

Ammonia Volatilization Loss From Surface Placed Urea-treated POME Pellets

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ABSTRAK

Ammonia yang hilang melalui pemeruapan dari baja urea yang digunakan pada tanah pendalaman Malaysia boleh mencapai 50% dari N yang diberi. pH yang tinggi terbentuk di kawasan-mikro bila urea terhidrolisis membuat NH_4^+ tidak stabil dan NH_3 teruap. Dalam kajian ini urea dimatrikan dengan POME (palm oil mill effluent) terasid dan dimampatkan bertujuan merendahkan pH kawasan-mikro bila urea terhidrolisis. Keupayaan pertukaran kation (KPK) POME yang tinggi akan meningkatkan daya tampan H dan kawasab herao NH_4^+ . Kajian menunjukkan urea-30% POME terasid dapat merendahkan NH_3 teruap ke paras 8% dari 30% pada until urea-sahaja. Penurunan NH_3 teruap selari dengan peningkatan POME dalam until urea-POME, peningkatan POME merendahkan NH_3 teruap. KPK dan daya tampan adalah sifat POME yang merendahkan NH_3 teruap dari urea. KPK dan daya tampan adalah sifat POME yang merendahkan NH_3 teruap dari urea. KPK yang tinggi menjerap NH_4^+ terhasil dari hidrolisis urea dan daya tampan H merendahkan pH kawasan -mikro.

ABSTRACT

Ammonia volatilization loss from urea applied to inland Malaysian soils can be as high as 50% of the nitrogen (N) applied. The high pH of the microsities developed upon urea hydrolysis results in NH_4^+ being unstable leading to (NH_3) volatilizing. In this study acidified POME (palm oil mill effluent) was matrixed with urea and pelletized with the objective of providing lower pH of the microsite during urea hydrolysis. The high cation exchange capacity (CEC) of the POME could also increase the H-buffering and sites for NH_4^+ adsorption. Results show that urea-30% POME acidified was able to reduce NH_3 volatilization loss to 8% compared with 30% of the urea-only pellets. Reduction in NH_3 volatilization loss was directly correlated with increase in the POME content in pellets. The higher the POME, the lower NH_3 volatilized. CEC and H-buffering are properties of POME that help reduce NH_3 volatilization loss. The high CEC adsorps NH_4^+ from the hydrolysis of urea and the H-buffering reduces the pH of the microsities.

INTRODUCTION

Ammonia volatilization loss from surface-placed urea in inland Malaysian soils can be as high as 50 percent (Pushparajah, 1982; Chan and Chew, 1984). The high NH_3 losses are due to the low H-buffering and low organic matter content of the soil coupled with favourable environmental conditions for volatilization to occur. Due to the high N loss from fertilizer urea, most oil palm and rubber plantations in Malaysia are fertilized with ammonium sulphate [$(\text{NH}_4)_2\text{SO}_4$] for the

N source. Urea in soil undergoes hydrolysis resulting in high pH in the area surrounding the urea granules (microsites) and often exceeds 8.5 (Fenn and Richards, 1986). Instability of ammonium at high pH results in it being volatilized (Vlek and Carter, 1983). Ammonia volatilization loss can be controlled by reducing microsite pH with acidic materials (Stumpe *et al.*, 1984). Increase in H-buffering of soils decreases NH_3 volatilization loss (Fenn and Kissel, 1976; Ferguson *et al.*, 1984). Ammonium,

the product of urea hydrolysis could be adsorped on exchange sites, thus soils with high cation exchange capacity (CEC) have lower NH_3 volatilization loss from urea applied (Fenn and Kissel, 1976; Fenn *et al.*, 1982). Our hypothesis is that POME (an agricultural waste material produced in abundance and which has high a CEC value) could, when modified to have a low pH and matrixed with urea, reduce NH_3 volatilization loss.

MATERIALS AND METHOD

Urea-POME Pellets

Urea-treated POME pellets were prepared by mixing 0.52 g ground urea with HCl-treated POME and pelletized at 3 tons using a hydraulic press. The HCl-treated POME was made by reacting 1 M HCl kg^{-1} POME. The urea-treated POME pellets had a diameter of 12 mm and thickness varied according to the POME content in the pellet. Levels of POME used were 10, 20 and 30% (w/w). Three treatments, urea-only, POME-only, and urea-20% POME unacidified pellets were tested. Each treatment had three replicates. Acidified POME has a CEC of 73 $\text{cmol}(+) \text{kg}^{-1}$ and a pH of 2.92, whereas unacidified POME has a pH of 6.58.

Ammonia Volatilization Loss Measurement

Volatilized NH_3 was measured using the method of Fenn and Kissel (1973). A Buchner flask was used as the air exchange chamber. Air was pumped through the exchange chamber at the rate of 20 chamber's volume min^{-1} and subsequently through an Erlenmeyer flask containing boric acid mixed indicator to trap NH_3 released. Volatilized NH_3 was determined daily by titrating the boric acid containing the trapped NH_3 with 0.01M HCl. Urea-treated POME pellets were placed in a nylon sieve pouch (30 mm sieve size, 5 cm L and 2 cm W) in the exchange chamber with 300 g soil (Munchong series, Isotropeptic Haplorthox, pH 4.36, N - 0.34%, C - 3.11%, clay - 51% CEC - 13.7 cmol kg^{-1} soil). The moisture content of the soil was maintained at 80% field capacity. Ammonia volatilization loss measurement was carried out for 7 days. At the end of Day 7, the pouch was retrieved and remains of the pellet and 10 g of soil surrounding it were analysed for pH and exchangeable NH_4 (KCl extractable, Bremner, 1965). This soil was considered as the microsite

region. A sample from the remaining soil was also taken and similarly analysed. This soil was considered as the outer soil region.

RESULTS AND DISCUSSION

N loss through volatilization of the urea-only pellet was 29.3% and from the POME-only pellet was negligible (Table 1). The level of acidified POME content in the urea-POME pellets was found to influence the extent of NH_3 volatilized, the higher the POME content the less NH_3 volatilized. Ammonia volatilization was reduced to 18, 12 and 8% when 10, 20 and 30% acidified POME respectively was matrixed with urea. Urea-20% POME unacidified had 17.9% N loss, indicating acidification of the POME had reduced N loss by 5.8%. The ability of the microsite to resist increase in pH during urea hydrolysis influenced the amount of NH_3 volatilized. POME has high CEC and its acidification creates high H-ions buffering of the microsite thus resisting the pH increase during urea hydrolysis. The influence of microsite acidification on NH_3 loss has been reported by Fenn *et al.* (1990) and Bremner and Douglas (1971) in studies where phosphoric acid was mixed with urea. This mixture, however, has the disadvantage of being corrosive and needs special care in handling. The influence of CEC of POME in reducing NH_3 volatilization loss can be deduced from the urea-20% POME pellets that are acidified and unacidified. Reduction in NH_3 volatilization loss due to the CEC was 12.1% and 5.8% was due to acidity. Ammonium from urea hydrolysis could be adsorped on the adsorptive sites of POME. Influence of CEC on reducing NH_3 volatilization loss has been reported (Du Plessis and Kroontje, 1964; Fenn *et al.*, 1982). Ammonia loss peaked on Day 2 for the urea-only pellet, Day 3 for the 10%, and Day 4 for the 20 and 30% POME content respectively. When acidified POME was compared with unacidified POME, acidification delayed the peak by one day. Delay in peak NH_3 loss resulted in an overall lowering in the cumulative NH_3 loss from pellets which could be due to lower urease activity (Delaune and Patrick, 1970).

Ammonium Adsorption

Table 2 shows the amount of ammonium adsorped on exchange sites of pellets and soils. No ammonium was recorded from the urea-only pellet as all had hydrolysed and nothing was left

TABLE 1
Ammonia volatilization loss (% of applied N) from urea-POME pellets

Pellets	Day							Total
	1	2	3	4	5	6	7	
urea	4.2 ^a	15.4 ^a	4.7 ^b	2.3 ^c	1.5 ^d	1.0 ^e	0.9 ^c	30.0 ^a
100% POME	0 ^b	0 ^c	0 ^d	0 ^d	0 ^e	0 ^d	0 ^d	0 ^e
10% acid POME	0.1 ^b	2.1 ^b	5.4 ^a	4.4 ^a	2.6 ^a	2.0 ^b	1.7 ^a	18.3 ^b
20% acid POME	0.2 ^b	1.0 ^{bc}	1.9 ^c	3.8 ^b	2.1 ^{bc}	1.7 ^c	1.4 ^b	12.1 ^c
30% acid POME	0 ^b	0.4 ^c	1.6 ^c	2.2 ^c	1.7 ^{cd}	1.2 ^d	1.0 ^c	8.1 ^d
20% POME	0.2 ^b	2.0 ^b	5.1 ^{ab}	4.4 ^b	2.3 ^{ab}	2.2 ^a	1.6 ^{ab}	17.9 ^b
CV (%)	59.3	19.8	9.5	5.9	12.5	5.7	13.3	6.2

Means followed by the same letter in a column are not significantly different at P=0.05 using DMRT

TABLE 2
Amount of ammonium adsorped on urea-POME pellet, microsite and outer soil

Treatments	Pellet (mg)	Microsite (mg g ⁻¹)	Outer soil (mg g ⁻¹)
urea	-	639.3 ^c	494.7 ^b
100% acid POME	175.0 ^d	58.3 ^d	84.0 ^c
10% acid POME	408.3 ^c	704.7 ^b	457.3 ^b
20% acid POME	781.7 ^b	704.7 ^b	485.3 ^b
30% acid POME	1201.7 ^a	765.3 ^a	711.7 ^a
20% POME	513.3 ^c	704.7 ^b	539.0 ^b
CV(%)	20.7	4.2	13.6

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the product of urea hydrolysis could be adsorbed on exchange sites, thus soils with high cation exchange capacity (CEC) have lower NH_3 volatilization loss from urea applied (Fenn and Kissel, 1976; Fenn *et al.*, 1982). Our hypothesis is that POME (an agricultural waste material produced in abundance and which has high a CEC value) could, when modified to have a low pH and matrixed with urea, reduce NH_3 volatilization loss.

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10% acid POME	0.1 ^b	2.1 ^b	5.4 ^a	4.4 ^a	2.6 ^a	2.0 ^b	1.7 ^a	18.3 ^b
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30% acid POME	0 ^b	0.4 ^c	1.6 ^c	2.2 ^c	1.7 ^{cd}	1.2 ^d	1.0 ^c	8.1 ^d
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20% POME	513.3 ^c	704.7 ^b	539.0 ^b
CV(%)	20.7	4.2	13.6

Means followed by the same letter in a column are not significantly different at P=0.05 using DMRT

of the pellet. Adsorbed NH_4^+ increased with the levels of POME in the pellets. This was due to the increase in the CEC of the pellets. Acidification of the POME significantly increased NH_4^+ adsorption compared with normal POME. The lowering of pH in the microsite had probably reduced the amount of NH_4^+ converted to NH_3 resulting in more NH_4^+ being adsorbed on exchange sites. The amount of NH_4^+ adsorbed approximately doubled for every 10% increase in POME content in the pellet. Ammonium adsorbed by microsites was similar for all levels of POME incorporated except for the highest POME level. The outer soil region had less NH_4^+ adsorbed compared with the microsites. The reduction in NH_3 volatilization from urea-POME pellets had resulted in more NH_4^+ being adsorbed on the pellets.

pH of Pellets and Soils

The pH of urea-POME pellets seven days after urea application was similar irrespective of the POME content (Table 3). Ammonium released upon urea hydrolysis had increased the pH of the urea-POME pellets as compared with the POME-only pellet, which had a pH of 4.85. The microsite pH was lower and the outer soil region had the lowest pH compared with the pellets. The influence of site distance from fertilizer

granule and time after fertilizer application on pH of soil was reported by Fan and MacKenzie (1993). They found that the sphere of influence of urea fertilizer on soil pH increases with time and was effective to 35 mm distance from fertilizer granule. In our experiment, the influence of microsite distance extends up to 15 mm and the outer soil up to 16-45 mm from the pellets. Since we only monitored the pH at Day 7, the daily pH is not known.

CONCLUSION

Pelletizing urea with acidified POME (30%) reduced NH_3 loss through volatilization from 30% to 8%. This reduction is explained by the increase in NH_4^+ adsorbed on the pellets, microsites and the outer soil of the urea-POME pellets. This in turn was due to the increase in the CEC of pellets by the presence of POME. Low pH and high H-buffering of the urea-POME pellet was observed when urea-acidified POME had higher NH_4^+ adsorbed on the pellets than for the urea-unacidified POME. Investigation on the effects of urea-POME pellets on plant N uptake efficiency under field conditions needs to be carried out in order to realise the potential of the pellets as a fertilizer N source.

TABLE 3
The pH of urea-POME pellets, microsite and outer soil at Day 7 after application

Treatments	Pellet	Microsite	Outer soil
urea	-	6.57 ^b	6.33 ^c
100% acid POME	4.85 ^b	5.04 ^c	5.03 ^d
10% acid POME	7.87 ^a	7.57 ^a	7.25 ^a
20% acid POME	7.98 ^a	7.49 ^a	6.94 ^b
30% acid POME	7.97 ^a	7.41 ^a	6.92 ^b
20% POME	8.02 ^a	7.46 ^a	6.97 ^b
CV(%)	1.44	1.6	1.54

Means followed by the same letter in a column are not significantly different at $P=0.05$ using DMRT

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